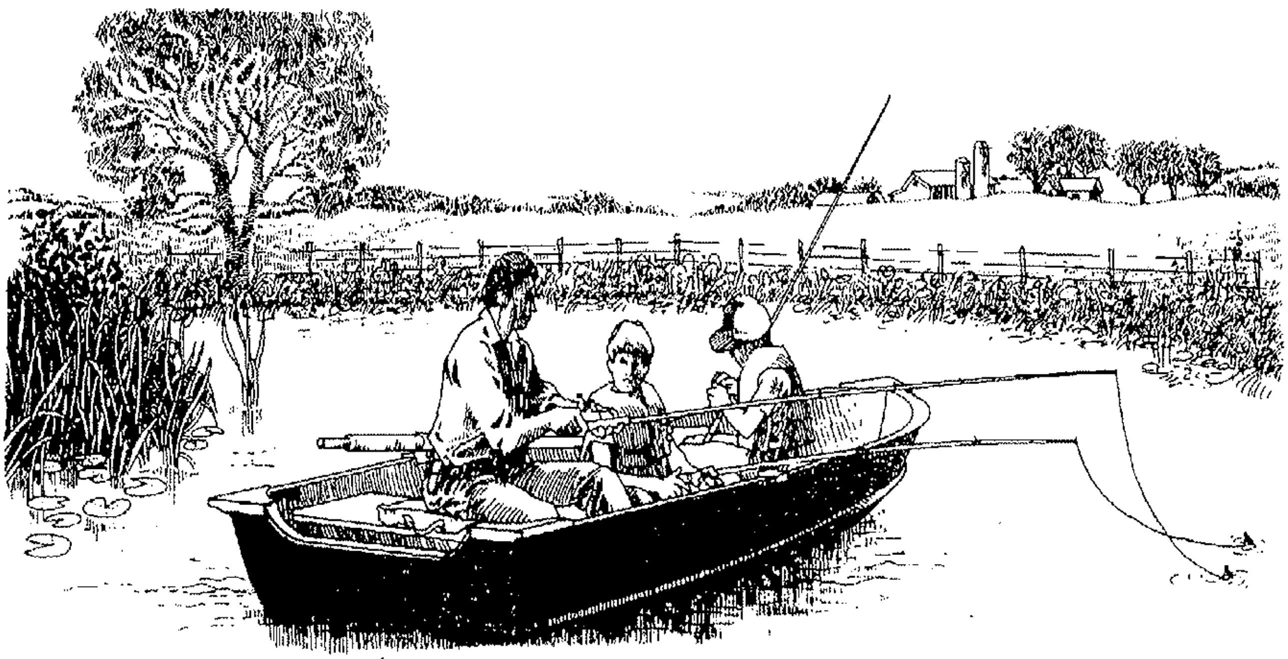
Bass Lake Alum Treatment

Project Description
&
Water Quality Update



Prepared by the
Marinette County Land & Water Conservation Department
December 2006

Charles Druckrey, Water Resource Specialist
Marinette County Courthouse
1926 Hall Avenue
Marinette, WI 43143-1717

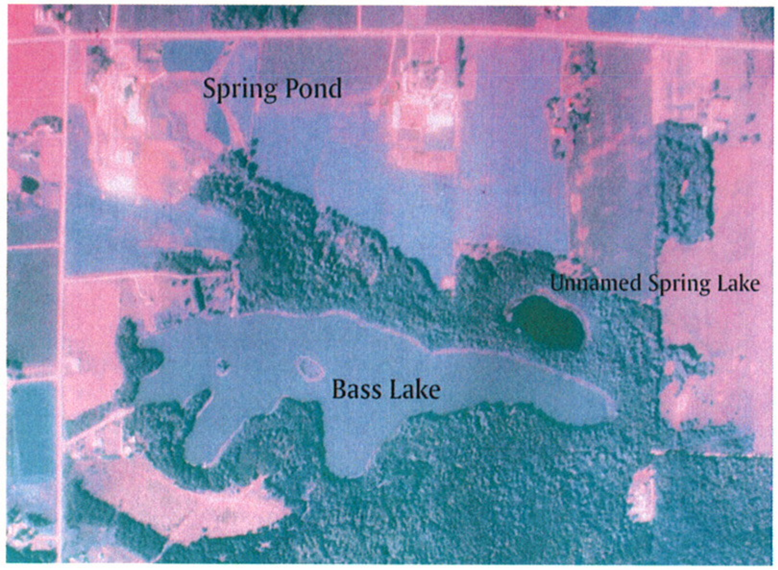


Figure 1. Bass Lake in Full algae bloom. The two watershed farms are located north of (above) the lake.

Project Setting

Bass Lake is a 37.4 acre, hard water drainage lake located in southwest Marinette County, Wisconsin. The Lake is located in an agricultural setting but retains a wild character (Figure 1). Development is limited to five dwellings located on the east end of the lake.

Bass Lake receives drainage from a small unnamed spring lake, a spring-fed farm pond, and several spring seeps located north of the lake. Surface runoff from approximately 451 acres of land also drains to the lake. Cultivated cropland and farmstead account for 83% of watershed land use. When restoration efforts began two dairy farms located immediately north of the lake owned and/or operated most of the cropland in the watershed. While most of the cropland is still in production, only one farm operation currently houses animals.

Bass Lake has a maximum depth of 62 feet and an average depth of 23 ft. Due to its small surface area and great depth Bass Lake experiences very strong thermal stratification (stratification factor = 42.7). Monitoring has shown that turnover is sporadic in Bass Lake and mixing is often incomplete.

Water Quality

Bass Lake has a long history of water quality problems caused primarily by animal waste runoff from feedlots and unconfined manure stacks. In the mid 1960's, the lake supported a diverse sport fishery and was popular with local anglers. The fish population included largemouth bass, northern pike, yellow perch and sunfish species. About this time the Wisconsin Department of Natural Resources (WDNR) began stocking brown trout as well. Trout stocking was suspended in 1975 however, after hypolimnetic oxygen concentrations declined and the lake could no longer support a coldwater fishery.

Subsequent winter fish kills decimated the lakes warm water fishery as well. Between 1977 and 1991, the average dissolved oxygen concentration measured one meter below the ice in late winter was 2.24 mg/l and regularly dipped below 1mg/l. During this period the fish population consisted primarily of minnows and rough fish.

The large hypolimnetic volume and tendency toward incomplete mixing during turnover contributes greatly to the propensity for severe algae blooms and fish kills in Bass Lake. On several occasions during the last 20 years the surface total phosphorus concentration after spring turnover exceeded 200 ug/l and early summer often saw severe algae blooms and extremely low water clarity.

Bass Lake also tends to experience fall turnover very late in the year. This often sets the lake up for winterkill conditions if ice cover occurs before the epilimnion has a chance to absorb much oxygen.

On at least one occasion a turnover event resulted directly in a fish kill on Bass Lake. Between 1996 and 1997 Bass Lake experienced very little mixing which lead to a buildup of anoxic, phosphorus rich water in the hypolimnion. By the summer of 1998 the hypolimnetic phosphorus level exceeded 1,700 ug/l. In mid November 1998 the lake turned over driving surface total phosphorus to 872 ug/l. The volume of anoxic water circulated throughout the lake was sufficient to drive dissolved oxygen down to 0.5 mg/l at the surface. Although hydrogen sulfide concentration was not measured it could be smelled ¼ mile downwind of the lake and was likely toxic to fish.

History of Runoff Pollution Control Efforts

Bass Lake was selected as a small-scale priority watershed project under the Wisconsin DNR Nonpoint Source Pollution Control Program in 1984. The goal of the project was to reduce runoff pollution to Bass Lake from agricultural sources located in the watershed. Both farm operations that were active at the time cooperated fully and installed the recommended best management practices (BMP) to reduce runoff pollution. These practices included clean water diversions, barnyard runoff controls, filter strips, roof runoff management, and installation of manure storage facilities to eliminate winter-spread manure and facilitate proper nutrient management.

As expected, internal phosphorus loading in Bass Lake continued to degrade water quality despite the many pollution control efforts. Long term monitoring of Bass Lake revealed that during periods of prolonged thermal stratification, hypolimnetic oxygen was quickly depleted and phosphorus was released from enriched lake sediment. Between 1977 and 1995 the average hypolimnetic phosphorus concentration was 490 ug/l. On several occasions phosphorus levels in excess of 1,000 ug/l have been recorded. By 1990 it was widely believed that internal phosphorus loading was entirely responsible for continued algae blooms and oxygen deficiencies in Bass Lake.

The Marinette County Land & Water Conservation Department (LWCD) applied for and received a Wisconsin DNR Lake Protection Grant in 1995 to inactivate phosphorus laden bottom sediment with alum. The alum treatment was originally scheduled to take place in July 1996. The treatment was postponed, however, after runoff event monitoring revealed continued elevated nutrient loads from the watershed. Runoff event samples collected below the farms in the summer of 1996 contained total phosphorus levels in excess of 16,000 ug/l. Further investigation confirmed that the large concrete barnyards and associated filter strips, although properly designed and maintained, failed to remove phosphorus, particularly dissolved reactive phosphorus from the runoff. In hindsight it was clear that, given the proximate location to the lake these practices were not the best alternatives.

The LWCD received a WDNR Targeted Runoff Management Grant in 1999 to revisit the barnyard runoff problem and develop a workable plan to reduce phosphorus loading. After discussing the continuing problem and reviewing management options, one farm operator in the watershed decided to explore a farm abandonment and easement to remove cattle from the site. Wisconsin Stewardship Program funds for critical area stabilization and fish management easements were utilized to make this abandonment and conservation easement a reality. More than 55 acres of cropland and almost 2000 feet of Bass Lake's shoreline were enrolled and are now permanently protected. Two water and sediment control basin / wetland restorations were also installed in the easement area using U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program funds to further

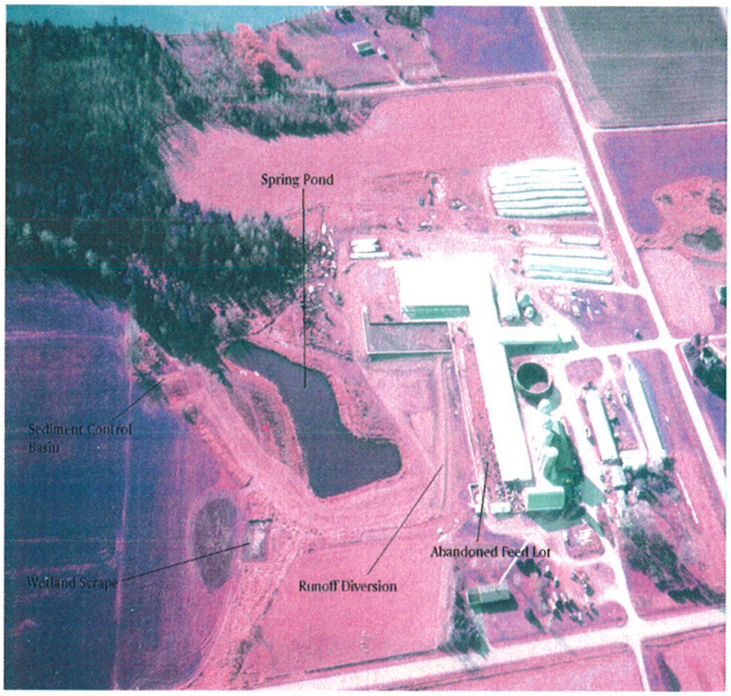


Figure 2. Watershed farm with best management practices.

reduce sediment and nutrient runoff from cropped fields and provide additional wildlife habitat.

On the second watershed farm, a concrete barnyard and filter strip was abandoned and all animals moved to a newly constructed freestall facility (Fig. 2). With this move, all animals on the farm were permanently housed inside and direct contact between animal waste and runoff was reduced to a minimum. Farmstead runoff was diverted away from spring seeps and routed through a newly constructed wetland scrape and sediment control basin. A second sediment control basin was planned as well as a leachate collection system to control runoff from silage bags and feed storage areas. Both watershed farms participated in nutrient management planning to better manage animal waste and further reduce nutrient applications to meet crop needs.

Water Quality Modeling

A v-notch weir and stage recorder were installed on Bass lakes inlet in 1997 and 1998 to collect flow and nutrient loading data. Although both summers were drier than normal the data clearly showed increased loading during runoff events (Fig 3). Water quality analysis revealed an average phosphorus concentration of 305 ug/l at base flow (<0.1 cfs). The high base flow concentration is likely due to loading from upstream wetlands that have absorbed manure-laden runoff for many years.

The Wisconsin Lake Model Spreadsheet (WILMS) was utilized to predict post alum application water quality given a base flow loading of 13.6 kg/year as predicted by the US Geological Survey Flux model. The WILMS model predicted a spring turnover phosphorus concentration of 12 - 24ug/l. Experience also suggested the lake would be able to assimilate the high base flow loading. Indeed, during previous periods where the lake did not mix surface water quality remained acceptable despite relatively high watershed nutrient loads. Bass lake is a hard water lake and marl formation appears to remove a significant amount of phosphorus from the epilimnion.

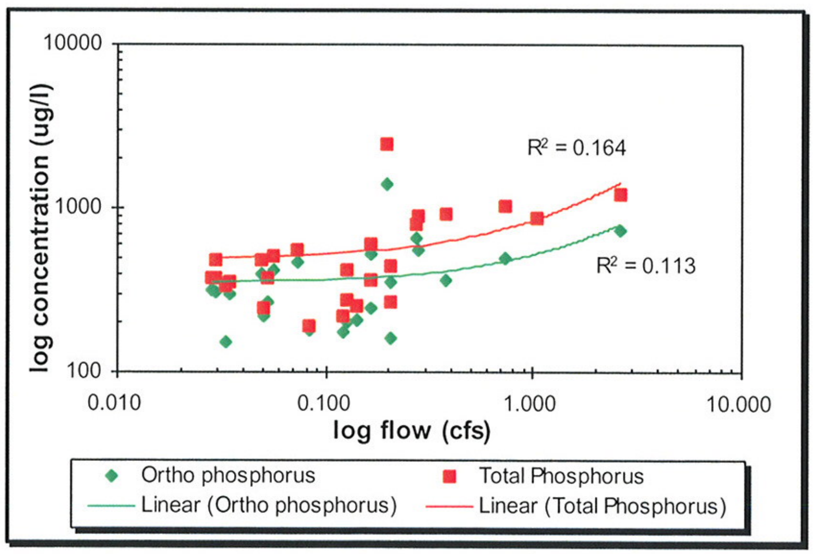


Figure 3. Bass Lake inlet – relationship between phosphorus and concentration.

Although a phosphorus mass balance was not conducted it was apparent that internal loading was primarily responsible for continuing water quality problems.

Alum Application

With the renewed effort to reduce watershed loading nearly finished it was decided to complete the alum treatment in 1999. The initial lake protection grant was for an alum dose of 12,250 gallons that would result in a concentration of 2.09mg/l of Al^{+3} throughout the water column. The dose was calculated based on phosphorus removal from the water column, a widely accepted method for alum dose determination. However, for best long-term results, new research on phosphorus inactivation recommended maximizing the dose to target sediment phosphorus release while also considering the lakes buffering capacity.

Using this method it was decided to drastically increase the alum dose to 61,000 gallons, for an in-lake concentration of 10mg/l of Al^{+3}. On an aerial basis the dose would result in an average of 91g/m^2 of Al^{+3} deposited on the sediment surface. On an aerial basis the final dose was higher than many other successful alum treatments that have been completed in Wisconsin.

Prior to the alum application a lab titration was completed to test the safety of the proposed alum dose. It was determined that the lake had sufficient buffering capacity to assimilate a dose of 21.9 mg/l of Al^{+3} without suffering a dangerous reduction in lake pH.

In October 1999 the contractor, Sweetwater Technologies Inc., applied 61,475 gallons of alum to the surface of Bass Lake during a two-day period. Weather conditions were favorable and the entire process was completed without complication (Fig. 4). Aluminum floc formation caused the lake to turn a cloudy blue color that lasted into the spring of 2000. Post-treatment water quality monitoring showed that the pH remained at or above 7.00 throughout the water column during and after alum application.

Figure 4. Alum application in progress.

Post Application Phosphorus Levels

Post application water quality monitoring clearly demonstrates the short-term effectiveness of the Bass Lake alum treatment (Fig. 5). Hypolimnetic total phosphorus, which averaged more than 400 ug/l and regularly exceeded 1,000 ug/l, before the alum treatment was reduced to 26 ug/l by the following spring. In the four years after the alum treatment hypolimnetic phosphorus averaged 31.1 ug/l despite continuing anoxia in the hypolimnion. During this time period dissolved oxygen profiles indicate the lake mixed completely in the spring of 2000 and nearly as well during fall turnover in 2001. Although no monitoring was completed during turnover periods in 2002 and 2003, chemistries and winter D.O levels point to adequate mixing during the period.

Since 2004 hypolimnetic phosphorus levels have risen noticeably. Between the summer of 2004 and fall 2006 hypolimnetic phosphorus averaged 136 ug/l with a

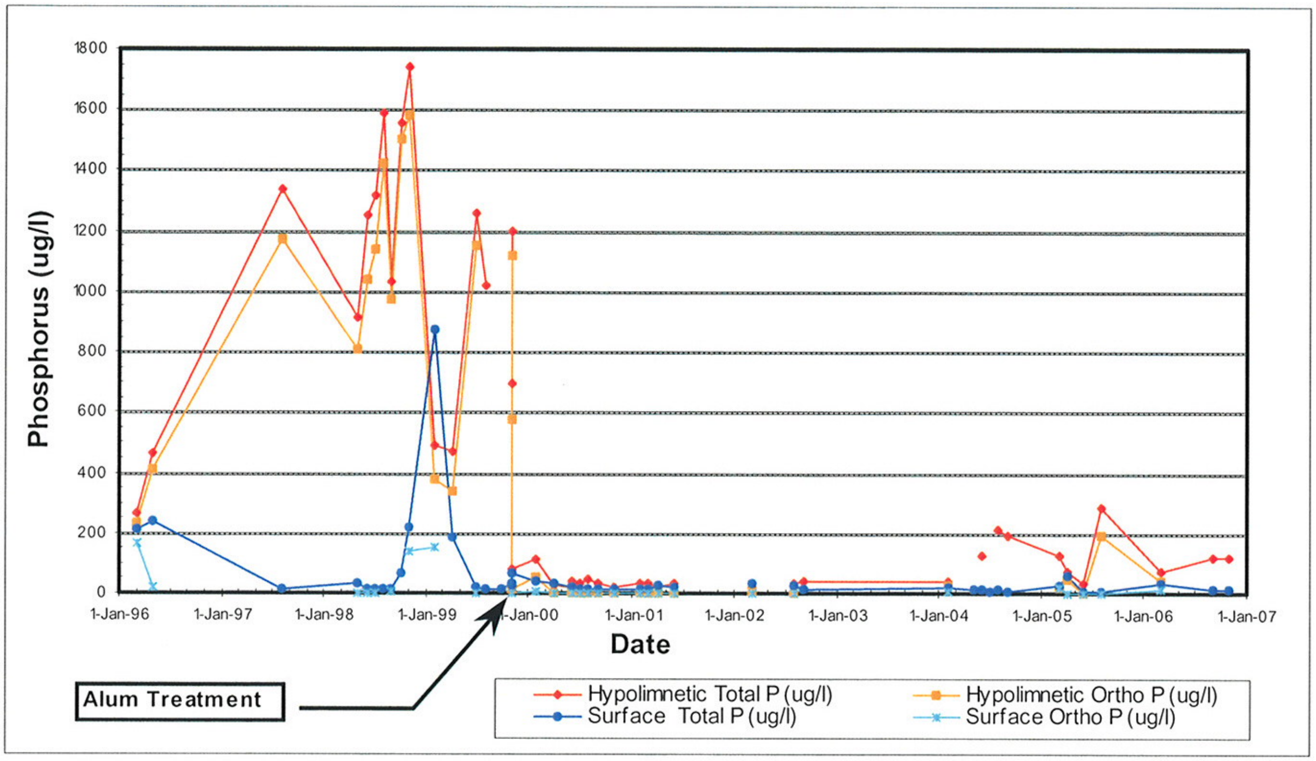


Figure 5. Bass Lake Phosphorus Concentrations

maximum of 284 ug/l. Incomplete mixing during turnover also marked the period. A review of dissolved oxygen profiles and phosphorus levels point to very little mixing in the fall of 2004 and the fall of 2006. Partial mixing during spring turnover in 2005 resulted in a significant spike in phosphorus in the epilimnion.

With the exception of Spring 2005 phosphorus levels in the epilimnion have remained relatively low. Prior to the alum treatment surface total phosphorus concentration routinely exceeded 200 ug/l at turnover and had surpassed 800 ug/l. In the six years since the alum treatment the average surface phosphorus concentration in Bass Lake was 18.9 ug/l.

Trophic State Improvements

The reduction in sediment phosphorus release has significantly reduced the frequency and severity of algae blooms in Bass Lake. Prior to the alum treatment chlorophyll-a averaged 34.6 ug/l and regularly exceeded 100 ug/l. During this period nuisance blue-green algae blooms were common and submersed macrophyte growth was suppressed. Since the alum treatment chlorophyll-a has averaged 5.2 ug/l and rooted macrophyte growth has increased considerably in the lakes narrow littoral zone.

The reduced algae growth has translated into greatly improved water clarity in Bass Lake. Between 1977 and 1999 the average Secchi disk depth was 6.5 feet with an average Secchi TSI value of 52.0. The average post treatment Secchi disk depth has nearly doubled to 12.5 feet with a corresponding improvement in Secchi TSI to 42.3 (Figure 6). Since 2001 the water clarity is even better with an average Secchi disk depth of 15.5 feet.

Dissolved Oxygen

While effective at reducing internal phosphorus cycling, alum does little to reduce sediment oxygen demand. For this reason, hypolimnetic oxygen levels in Bass Lake have not significantly improved since

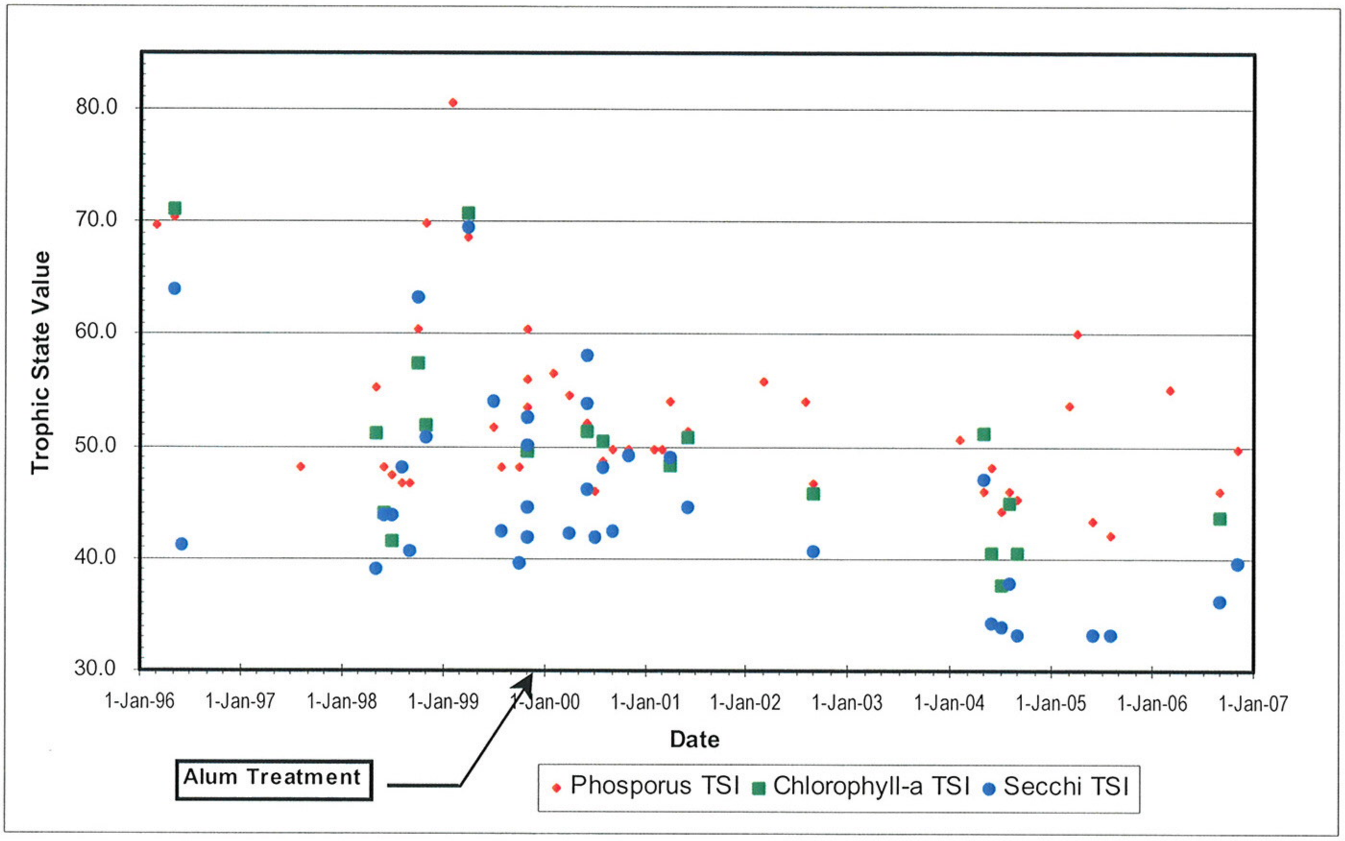


Figure 6. Bass Lake Trophic State Values

the alum treatment. A review of dissolved oxygen profiles shows no change in the location of the thermocline but does indicate slightly improved oxygen levels immediately below the thermocline since the alum treatment. This is due to the increased water clarity that allows for algae growth and oxygen production in the cooler waters of the metalimnion.

With only a slight improvement in oxygen concentration Bass Lake is still at risk for fish kills due to inadequate dissolved oxygen or toxic levels of hydrogen sulfide. Oxygen deficiencies are most likely to occur if the lake experiences a late turnover with little time for oxygen exchange prior to ice formation. As in the past, a sudden release of toxic hydrogen sulfide from the hypolimnion is a possibility if the lake turns over after a prolonged period of no, or incomplete mixing.

Future Monitoring Needs

The recent increase in hypolimnetic phosphorus, while significant, has not yet translated into decreased water clarity in Bass Lake. It remains to be seen if this increase represents a decrease in the effectiveness of the alum treatment or if it is a result of watershed loading. Future monitoring efforts should attempt to discern the current internal sediment phosphorus release rate and monitor watershed inputs to determine watershed loading and evaluate BMP effectiveness.